Clear-Sky Detection Algorithm

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18 September 2002

Outline

- Requirements
- Methodologies, description and assessment
- Comparison of Algorithms, status of methods
- Assessment of Errors - short wave discriminants
- Long wave discriminants - preliminary results
- Conclusions

Clear-Sky Identification
Why is it Important?

- The AIRS Science Team needs to work with uncontaminated (simple) data. We (JPL) have attempted to collect applications of clear sky detection algorithms from the Science Team and define requirements based on these needs
- We are working to have algorithms defined for inclusion in PGE by mid-October

Uses of Clear-Sky Radiances

- Validation of radiometric calibration
  - viewing of ocean surface, are the gains accurate, precision (noise) valid, radiances biased?
- Forward model validation
  - is the spectroscopy right, are there any unexpected “features”?
- Validation of cloud-cleared radiances
  - are the cloud-cleared radiances equal to the original radiances for clear footprints, are cleared radiances next to clear footprints similar?

Requirements

- One procedure will not satisfy all needs
  - Trade-off between false clears and missed cases.
  - Will need to boot-strap identification procedure as AIRS algorithms and products improve
- Ordering of needs based on quality and amount of clear data needed

Use	Amount	Accuracy
Forward model	10's	$<$ NeN
Radiance	1000/yr	~ NeN
Cloud-clearing	1,000's	1-2 NeN

Requirements
Assessment of the Quality

- Accuracy: an estimate of the maximum amount of radiance from clouds at 4μm and 8.9μm.
- Will attempt to assign independent error to each footprint
  - (will not be in place for mid-October delivery)

- Why and how do we improve our yield rate while not admitting cloudy scenes?

- Review proposed algorithms and provide an initial assessment accuracy

Procedure

- Seven algorithms were developed
  - based on combinations of 5 methodologies
  - applied a threshold against a discriminant to say cloudy true/false
  - no attempts to gauge accuracy
  - use long wave (9-11μm), visible during day, short wave
- JPL compared results and implemented some methods on simulated data

Methodologies

- Scene Coherency
  - standard deviation or gradient of radiances in adjacent footprints or 3x3's
  - heterogeneity in scene is indicative of clouds
- Split Window
  - regression of 2 or more channels (e.g. 9 and 11 μm) with differing atmospheric transmissions
- Clear Scene Radiance Prediction
  - difference of surface channel radiance with prediction using correlative data, e.g. analysis, radiosonde, buoy....

Methodologies (cont)

- Cloud Signature
  - cirrus and water clouds have spectral signatures,
  - similar to split window with different interpretation
- Cloud detection using Visible Channels
- Independent Data Sets (MODIS, GOES…)
- Output from Retrieval

- Last two are not viable, but useful for development and quality assessment.

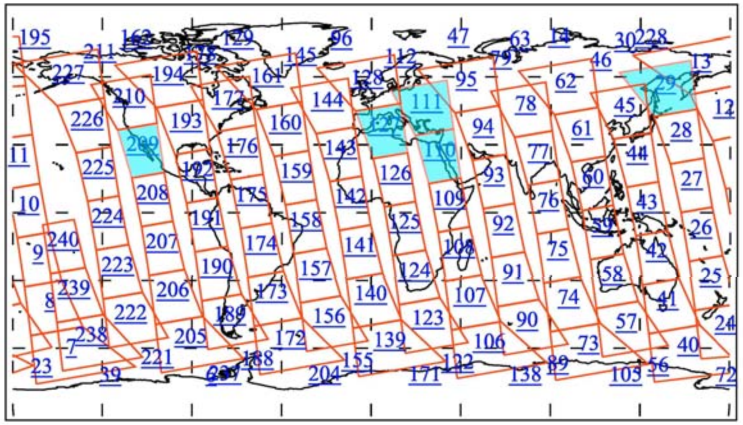
Methods Incorporated in Submitted Algorithms

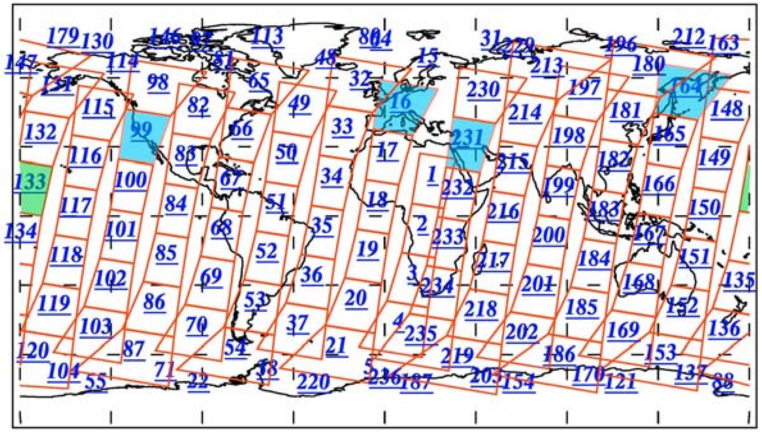
	Split Window	Coherency	Cloud Signature	Radiance Prediction	Independent Instruments
GSFC		1st Pass Cloud Clearing Noise			
JPL	X	X			
JPL-HHA		X			
NOAA-LM	X	X	X		
NOAA-MG	X	X		X	
UMBC	X	X		X	
SSEC	X	X	X		X
Vis/NIR			Cloudy pixel identification		

Assessment of Provided Data

- 9 granules of data 20 July 2002
  - Day: 29, 110, 111, 127, 209
  - Night: 16, 99, 164, 231

Day

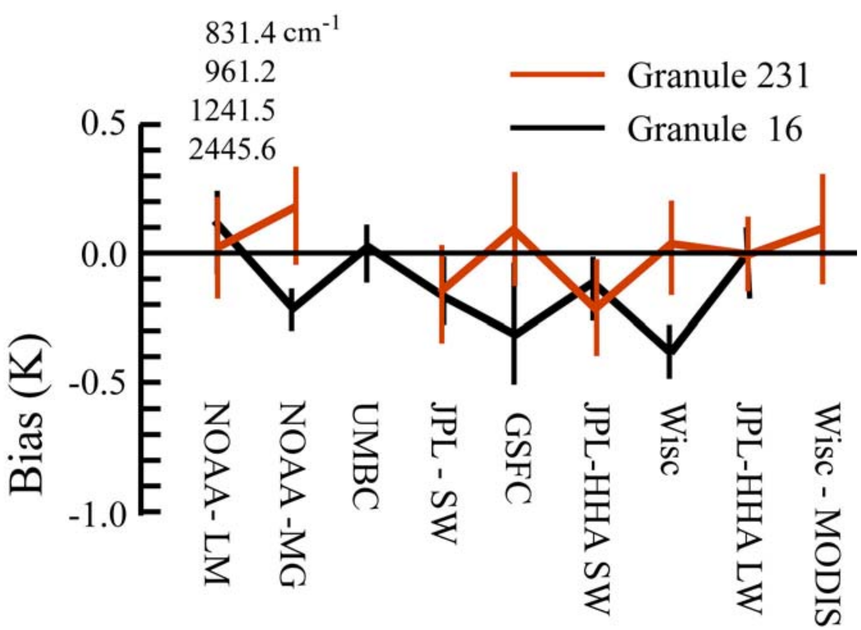




Night

- Cloud contamination inferred from calculated - observed radiances (K)
  - noise-free, cloud-free, land emissivity equals 1

Bias Assessment
(Obs. - Calc)



Yield

Method	Granule 16	Granule 231
NOAA-LM	865	339
NOAA-MG	927	293
UMBC	111	
JPL-SW	930	350
GSFC	212	54
JPL-HHA-SW	491	209
Wisc	845	372
JPL-HHA-LW	1051	473
Wisc-MODIS		125

Conclusions

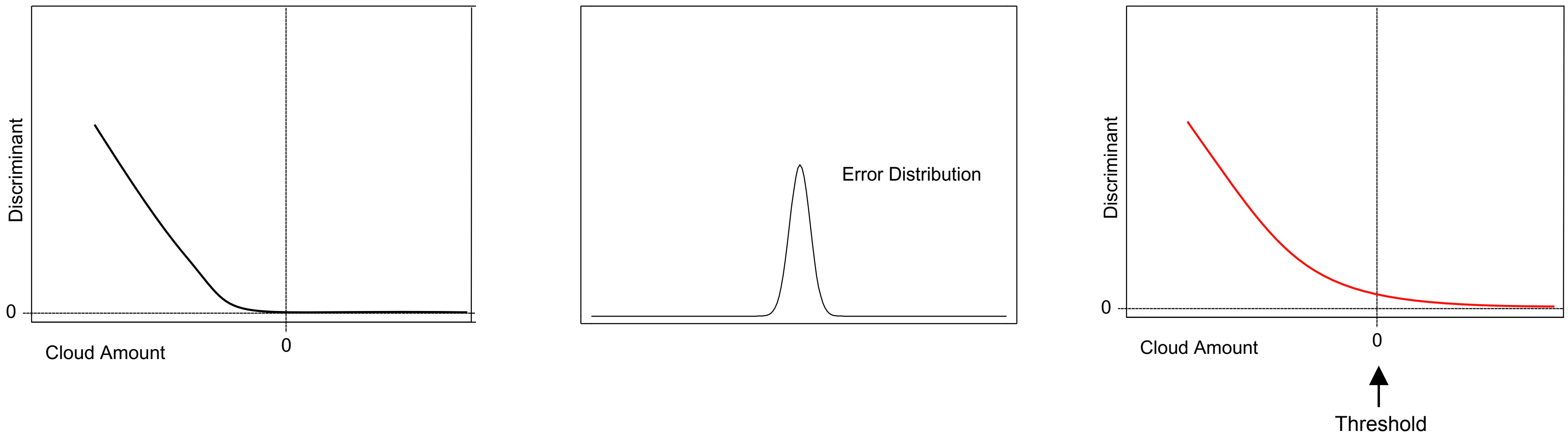
- No one method is best
- Bias is not perfectly anti-correlated with yield
- Quality is not correlated between methods
  - Logically and'ing methods produces substantially lower yields, but not consistently improved biases
- Errors on a per footprint level have not been addressed
- Various requirements suggest providing discriminants and let user apply threshold
- Methods will not meet requirements

Hypotheses

- All methods have error sources.
  - combining tests will not improve bias for correlated errors (bias could enter from O-C assessment)
  - combining tests will degrade yield if uncorrelated errors are not combined.
- Quality may be improved by combining discriminants, not tests
- Errors sources have not been addressed
  - identify error sources on a method by method basis
  - reduce by modifying discriminants or combining to reduce errors

Illustration of Error Sources

- Impact of errors on setting thresholds for discriminants



- Threshold is set to account for error broadened discriminant
  – but if error source is broad compared to requirement, threshold must be set high

Procedure

- Focus on night over ocean short wave discriminants
  - coherency discriminants
  - radiance prediction discriminants
- Optimize discriminants
  - minimize errors using simulated data
- Explore characteristics globally
- Explore errors with focus granule
  - 133 on 20 July 2002

Radiance Prediction Discriminants

- Involves an estimate of surface temperature, corrections for surface emissivity and atmospheric transmittance and emission
- Example 1: emission angle and surface temperature

$$f(T_s, T_{2616}, sza) \quad T_S \quad T_{2616} \quad 0.3458 \quad \frac{0.4708}{\cos sza}$$

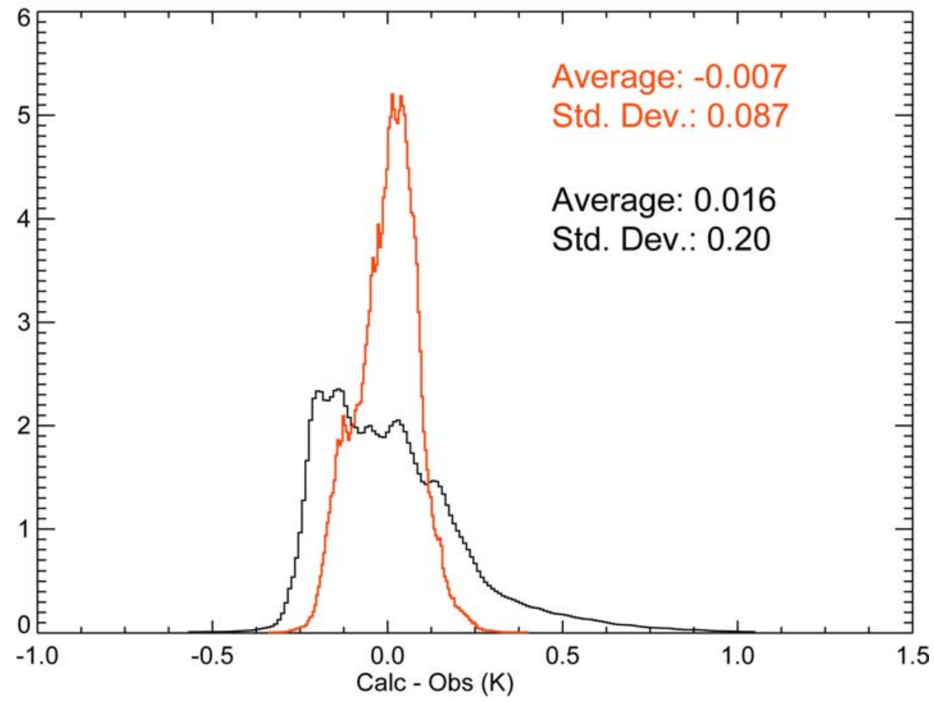
- Example 2: emission angle, surface temperature and emissivity

$$f(T_s, R_{2616}, sza) \quad B_{2616}^{\;1} \, B_{2616}(T_S)\, 1 \quad \frac{0.117}{\cos(sza)} \quad \frac{0.0967}{\cos(sza)\,\varepsilon_{2616}(sza)} \quad 0.045$$

$$B_{2616}^{\;1} \quad \frac{R_{2616}}{\varepsilon_{2616}(sza)}$$

Radiance Prediction Discriminants
Application to Cloud Free Data

- Simulated Data, 240 granules on 2002 July 20
  - No noise or clouds
  - Filtered data for oceanic night time footprints
    - Night (solar zenith angle > 90°)
    - Ocean (land fraction = 0.0)
    - Surface Temperature > 270K
  - 756,254 footprints
- Precision of method good to 0.1K



Radiance Prediction Discriminants Error Sources

- Uncertainty of correlative surface temperature
- Uncertainty in emissivity from angle/wind dependence of emissivity model
- Uncertainty of transmissivity, primarily from water
- Modeling of solar reflected (daytime)

Radiance Prediction Discriminant Coherency

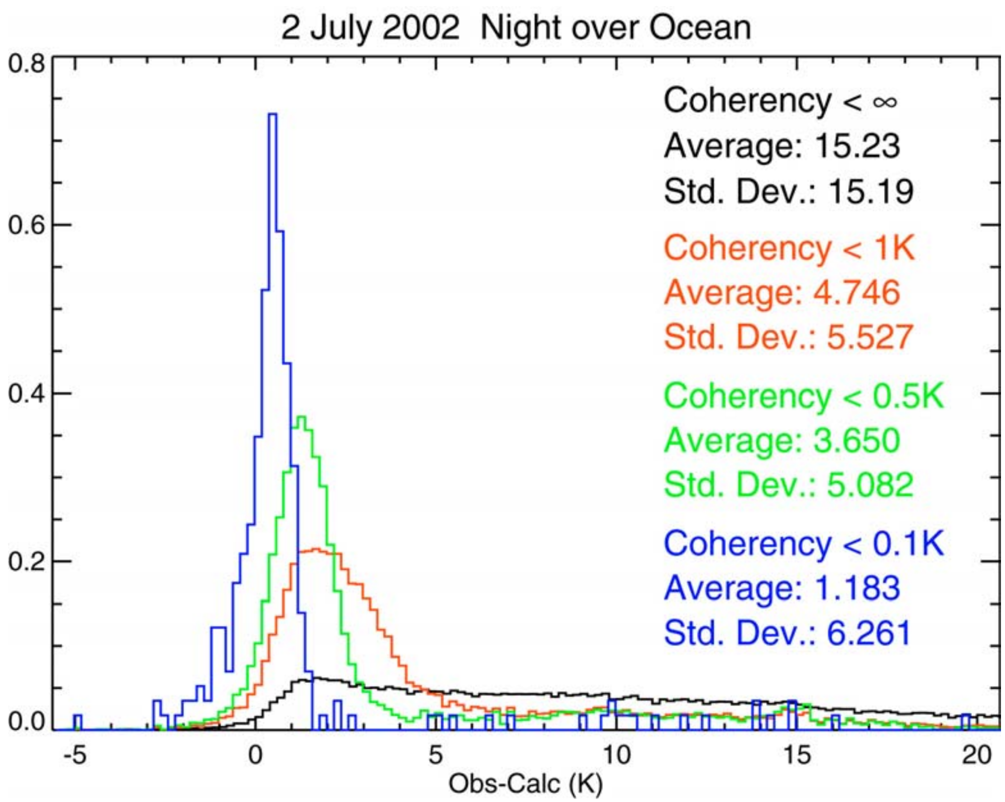
- Absolute value of difference
  - noise roughly $\sqrt{2}\text{NeN}$
- Standard deviation of 3x3
  - noise roughly $\frac{\sqrt{10}}{3}\text{NeN}$
- Primary error source
  - variability of surface temperature
  - variability of emissivity from angle/wind dependence of emissivity model
  - variability of transmissivity from water and slant path
- Same error sources but through variability
- Can 2616 cm^{-1} coherency test be used during day?

Application to Observations

- Same conditions as simulated data
- Estimate global accuracy of methods with intercomparisons
  - independence of error sources
  - same sources, but one is absolute and other is differences

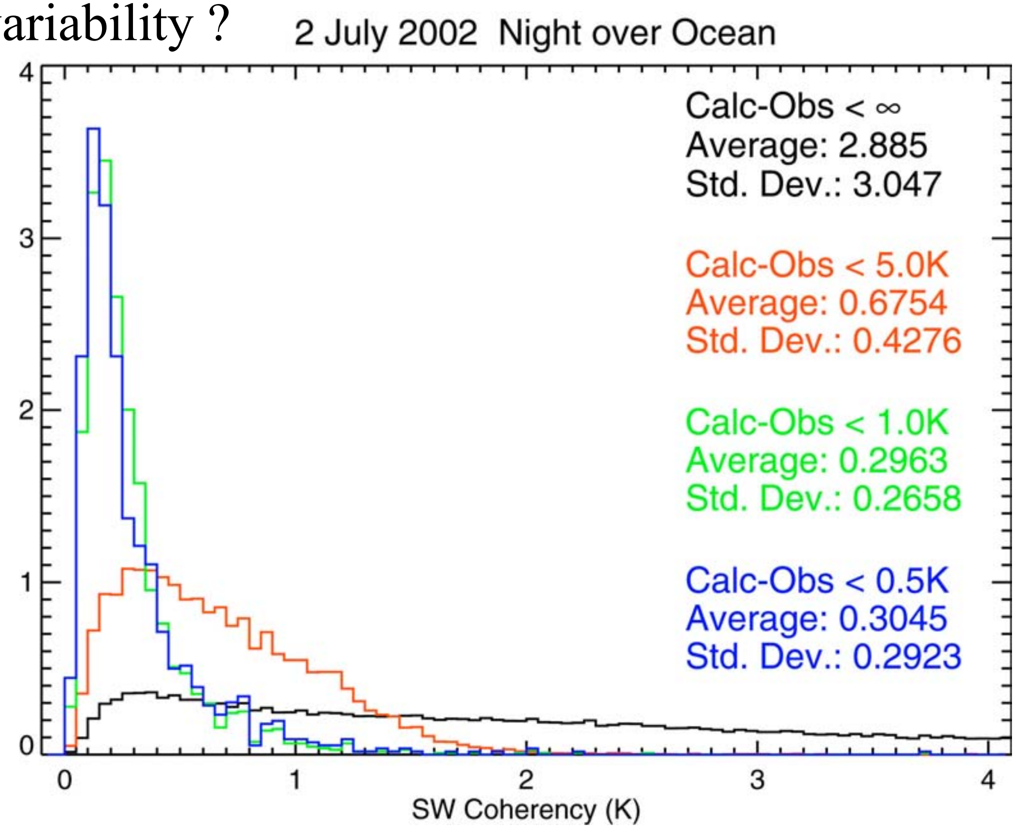
Accuracy of Methods

- As coherency threshold decreases second discriminant reaches asymptotic width
  - homogenous cloud ?



Accuracy of Methods (cont)

- As Obs-Calc threshold decreases coherency approaches asymptotic width
  - width much larger than previous thresholds
  - local variability ?



Error Estimates

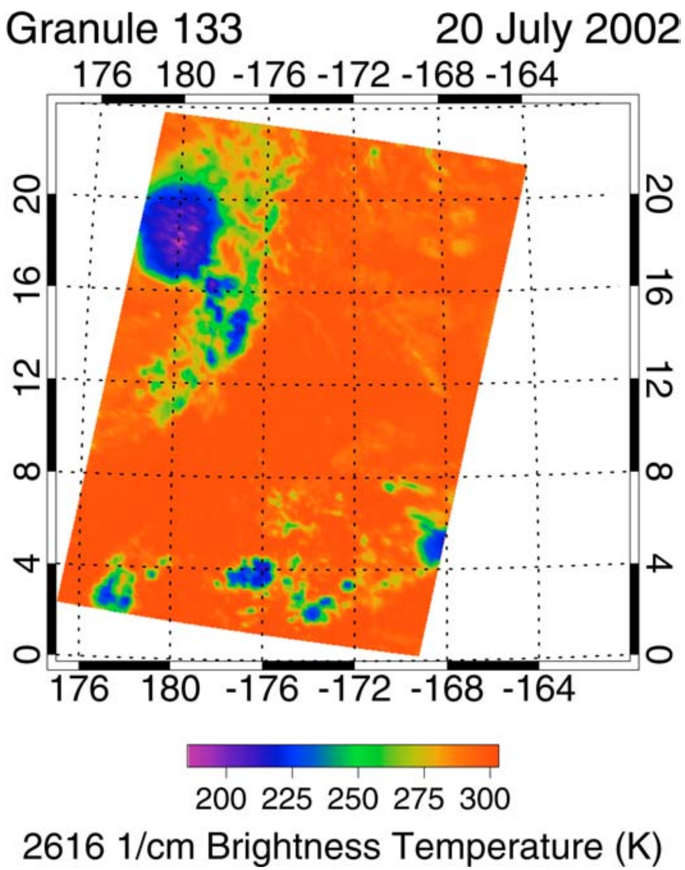
- Histogram of coherency asymptotes when Obs-Calc = 1K
  – suggests that prediction tests with this correlative data is no better than 1K
  – still potentially useful to remove uniform cloud decks.
- Accuracy of coherency test more difficult to ascertain

Granule 133 Focus Study

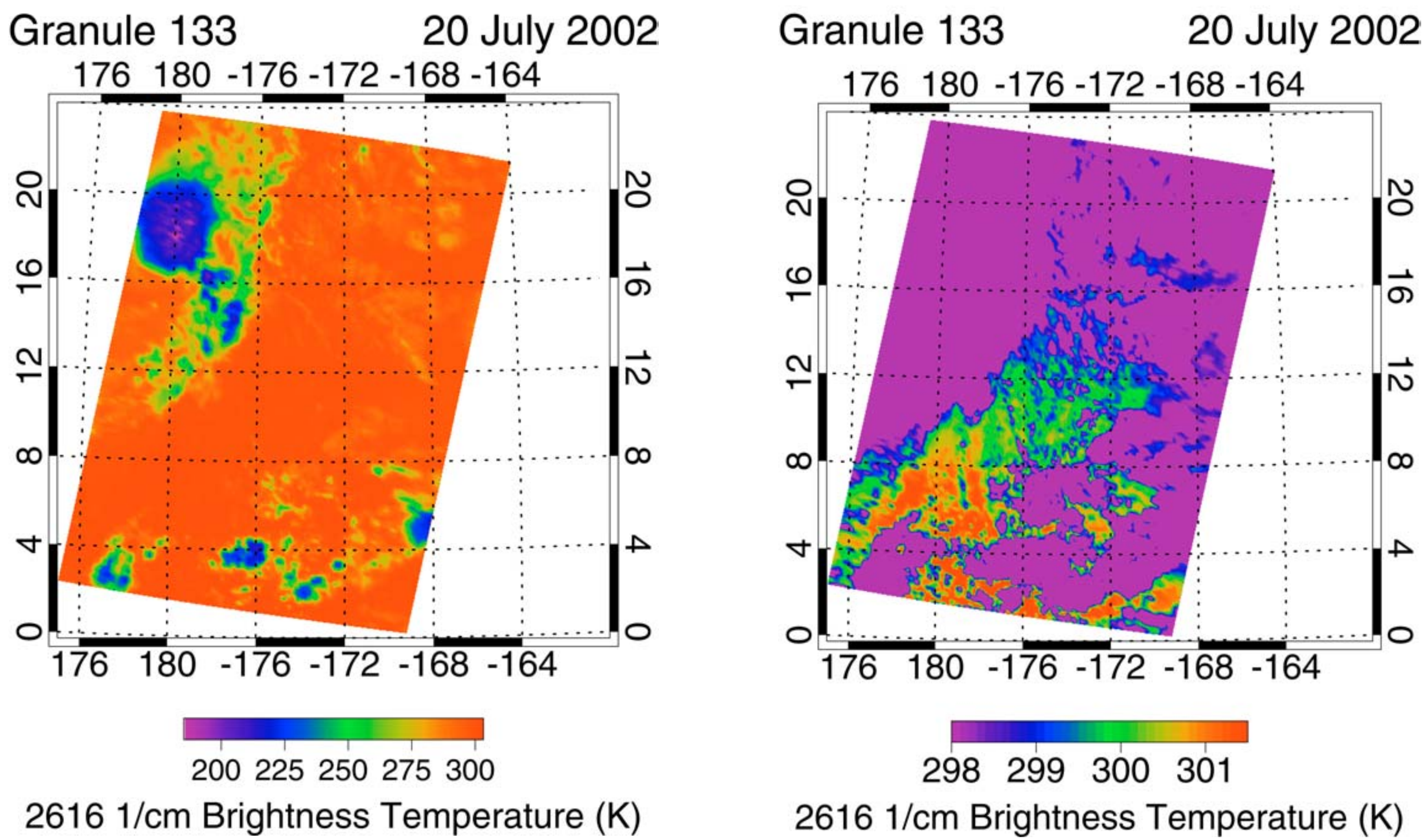
2616 cm^{-1} Brightness Temperature

- Tropical depression 18° N, 180°W
- ITCZ deep convection near 4° N

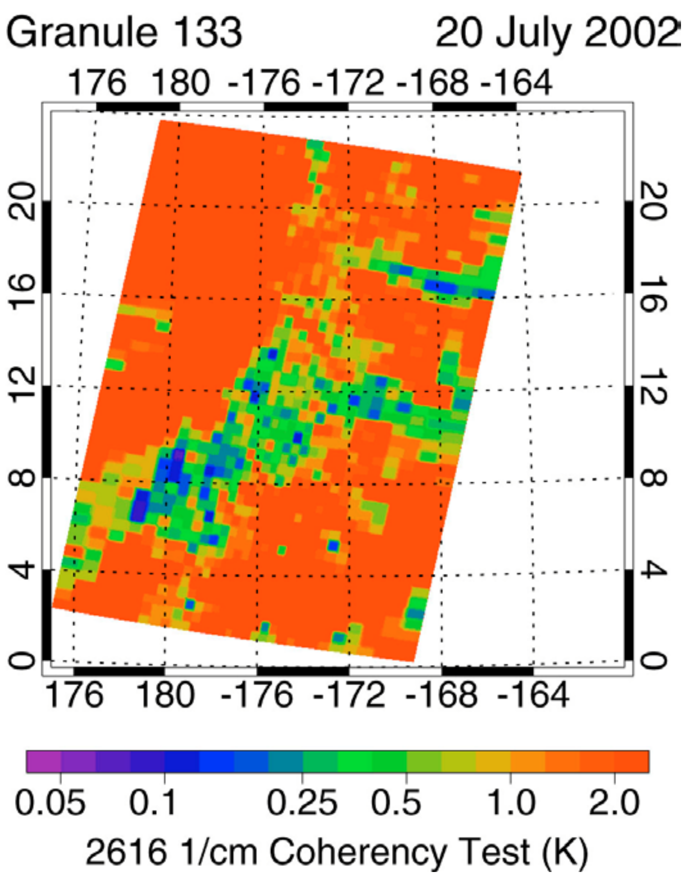
- Bands of cirrus east of depression
- Region of potential clear sky south of depression

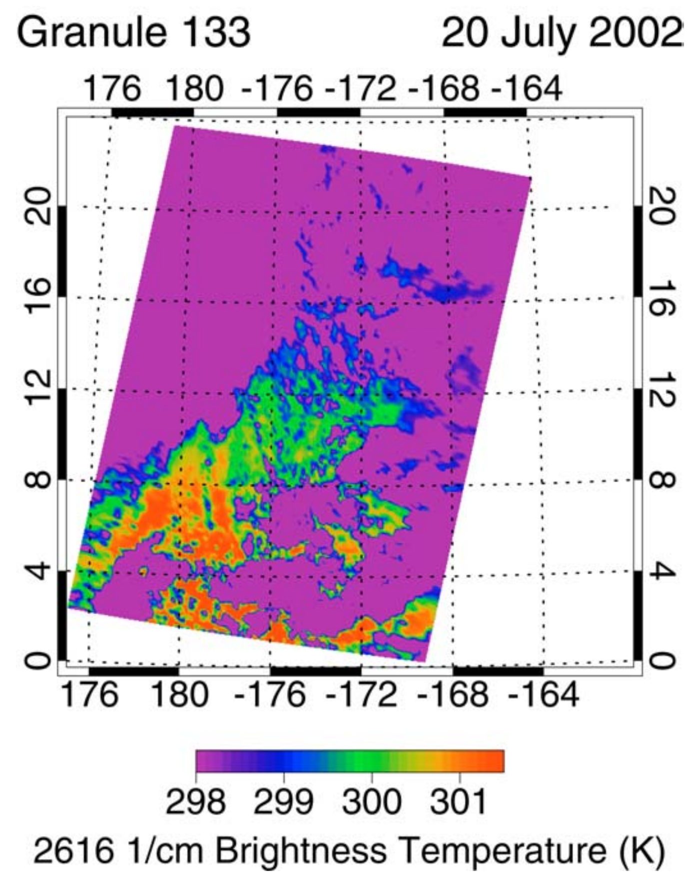


Granule 133 Brightness Temperature

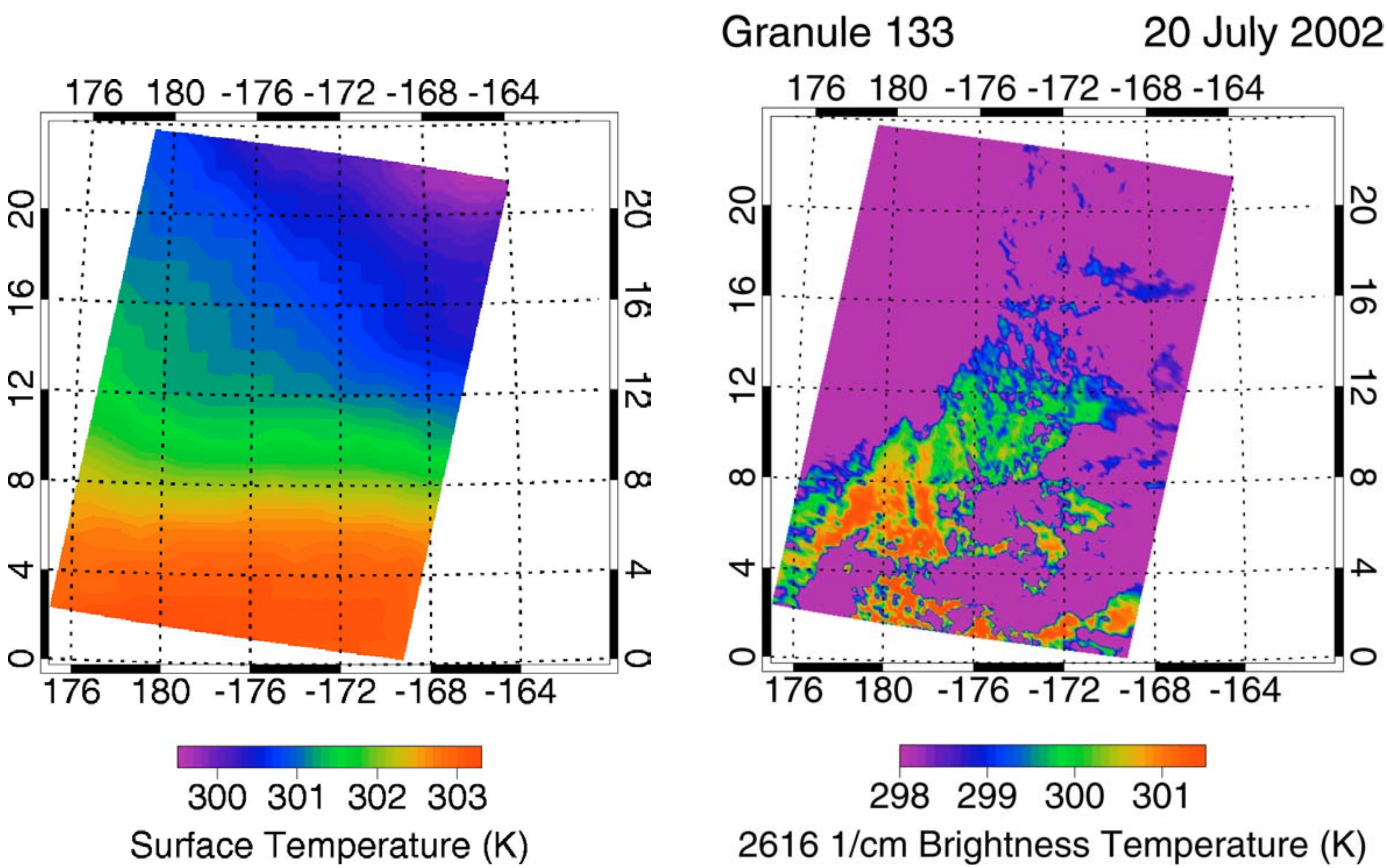


Granule 133 Coherency





Surface vs Brightness Temperature

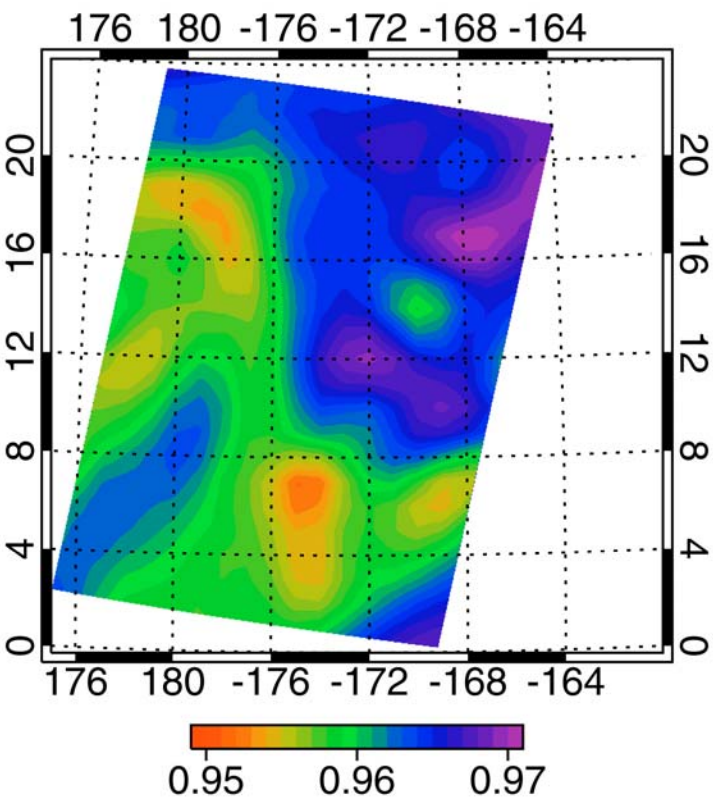


Surface vs Brightness Temp (cont)

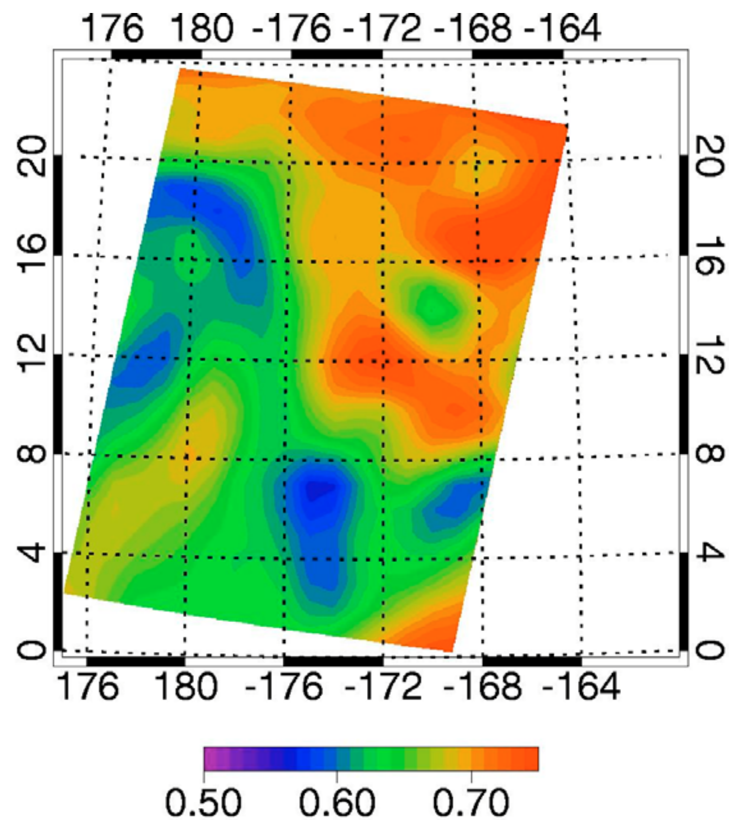
- Has a clear spot been detected?
  - ~1K colder than surface temperature
  - has gradient in approximately right direction
- How reliable is the surface temperature?
  - derived from buoy and AVHRR (Navy)
  - AVHRR tuned to match buoy
  - how accurate is hole searching with AVHRR?
- If this is a low cloud how to distinguish it from the surface?
- **Automated algorithm in place in October will be accurate to about 0.5-1K**.

Long Wave Discriminants

- How accurate are split window/prediction methods?



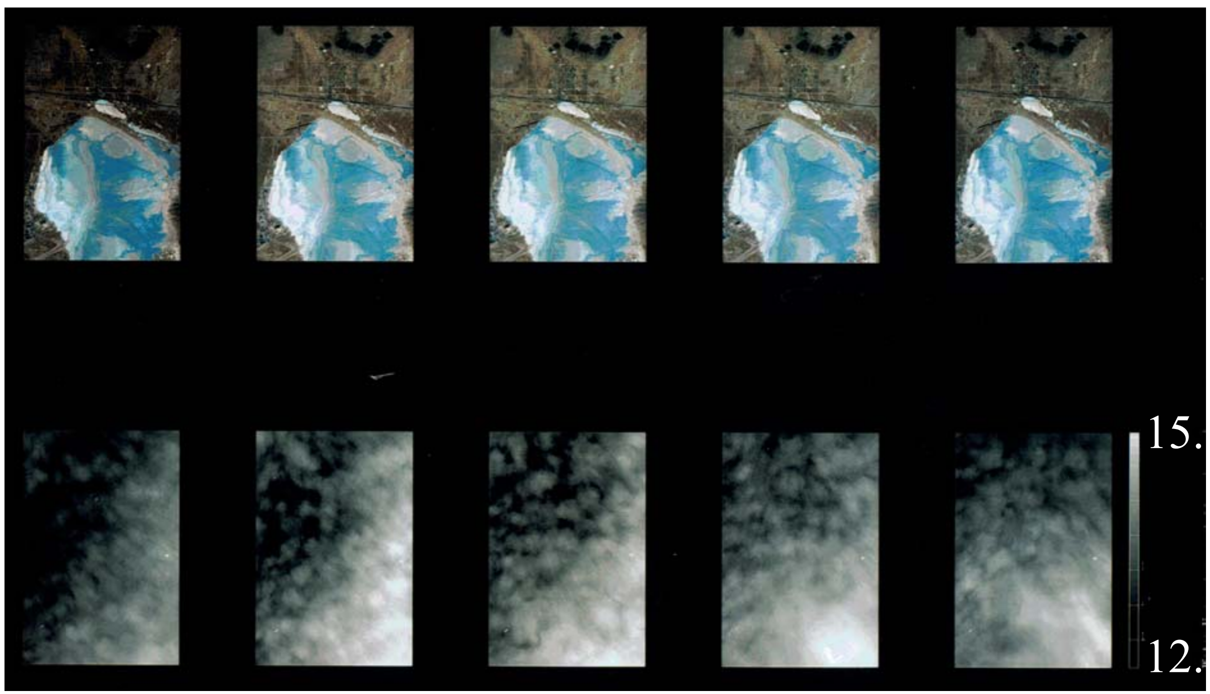
2616 cm^{-1} Slant-Angle Corrected Transmission



1127.7 cm^{-1} Slant-Angle Corrected Transmission

Long Wave Discriminants

- Current algorithms use 900, 918, 938, 965, 1017, 1228 and 1237 cm^{-1}, 1127 $cm^{-1}$is the most transmissive channel?
- Absorption is 20x larger
- Impact of water vapor modulation on variance



Conclusions

- Using input from science team, we are on schedule to have automated cloud discriminants in PGE
- High thresholds applied to discriminants reduces error, but false detections still occur. Manual assessment required.
- Radiance prediction discriminants have an accuracy of around 0.5-1K with current correlative data
- Accuracy assessment of long wave discriminants progressing on schedule